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Zeeman Effect and Ruby Laser Polarization*

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The Zeeman effect in addition to splitting the emission lines of atomic transitions results in definite polarizations of the different lines dependent on the orientation of the magnetic field with respect to the light path. For example, radiation emitted perpendicular to the magnetic field is linearly polarized parallel or perpendicular to the direction of the magnetic field according to whether the magnetic moment in the direction of the field remains the same or is increased or decreased by the quantum amount. Light emitted parallel to the magnetic field is circularly polarized with left-hand rotation or right-hand rotation dependent on whether M increases by one or decreases by one.

Many advantages are evident if one possesses the ability to determine the polarization of a laser output by subjecting the lasing medium to a controllable magnetic field. Modulation of the amplitude of the beam as a function of linear polarization is one desirable prospect.

An investigation of the possibility of accomplishing this polarization control in a solid state laser has been initiated. Ruby was investigated first for several reasons. A great deal of theoretical and experimental work on the properties of ruby has been published and the availability of the crystals was an important factor. The output from a ruby laser is randomly polarized for a 0 degree rod and is polarized perpendicular to the C axis for a 90 degree rod.[1]

A recent letter[2] suggests that double refraction of the light in the laser cavity is responsible for the polarization in a 67 degree rod. The

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authors failed to mention the relative magnitudes of the transition probabilities which are a result of the crystalline field of the ruby and create different effective gains for different polarizations of light with respect to the crystal axis. The laser oscillates in the mode with the highest gain which depends on both the transition matrix of the medium and the Q of the optical cavity. For the 0 degree rod the transition probability is equal for any polarization and the output is not polarized. The 90 degree rod output is linearly polarized perpendicular to the C axis and agrees with the maximum transition probability in this direction. No effect should be experienced by double refraction for this rod.

The marked difference in the matrix factor for varied polarizations shows the strong effect of the crystal electric field on the chrome ion transitions and made the prospect of altering the polarization by application of a magnetic field rather poor.[3] A detailed series of experiments was made to determine whether uniform magnetic fields up to 8,000 gauss would alter the polarization of the laser output. Data was taken for the set up indicated in the Figure 1. The output at the rear of the laser rod was monitored by a 925 phototube and the output from the front was passed through a polarizer and detected by a second 925 phototube. The outputs of the phototubes were integrated and observed on a dual trace scope. The data of observations of the output were normalized by dividing by the rear monitor output. This technique was necessary since the laser output varied considerably from pulse to pulse despite careful timing of flashes and the use of a regulated power supply to charge the storage capacitors.

The results of the experiments showed no change in the polarization of the output for uniform fields perpendicular to the axis of the laser with magnitudes up to 8,000 gauss for either the 0 degree rod or the 90 degree rod. The linear polarization of the 90 degree rod was very accurately portrayed by the comparison of the data with a $\cos^2\theta$ curve as shown in Figure 2.

The effect of magnetic fields on the microwave beats in the output of a ruby laser was investigated also. Beat frequencies at 1640 mc and 3280 mc were observed using a silicon semiconductor diode detector. These frequencies correspond to the fundamental mode frequency of the 2" ruby rod used in the experiments and double that frequency. The only reproducible effect observed was that the amplitude of the microwave beating was considerably reduced by the application of a magnetic field of sufficient intensity to counteract the magnetic field produced by the exciting current in the linear flash tube.

Work is continuing on other solid state materials which do not present the formidable obstacle of a powerful crystal field as does ruby.

Figure Captions

Fig. 1. Experimental set up for polarization measurements of ruby laser output.

Fig. 2. Graph of the relative intensity of the laser light output when passed through a polarization analyzer for the case of a 90° ruby. The solid curve is a $\cos^2\theta$ curve.

References

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(2) K. Miyaji, T. Nakano, T. Anbe, Y. Sakai, "Polarized Character of Ruby Laser", Proceedings IEEE (Correspondence) Vol. 51, No. 6, p. 935, June 1963.

(3) S. Sugano and I. Tsujikawa, "Absorption Spectra of Cr^{+++} in Al_2O_3 - Part A", J. Phys. Soc. Japan, Vol. 13, p. 899, 1958.

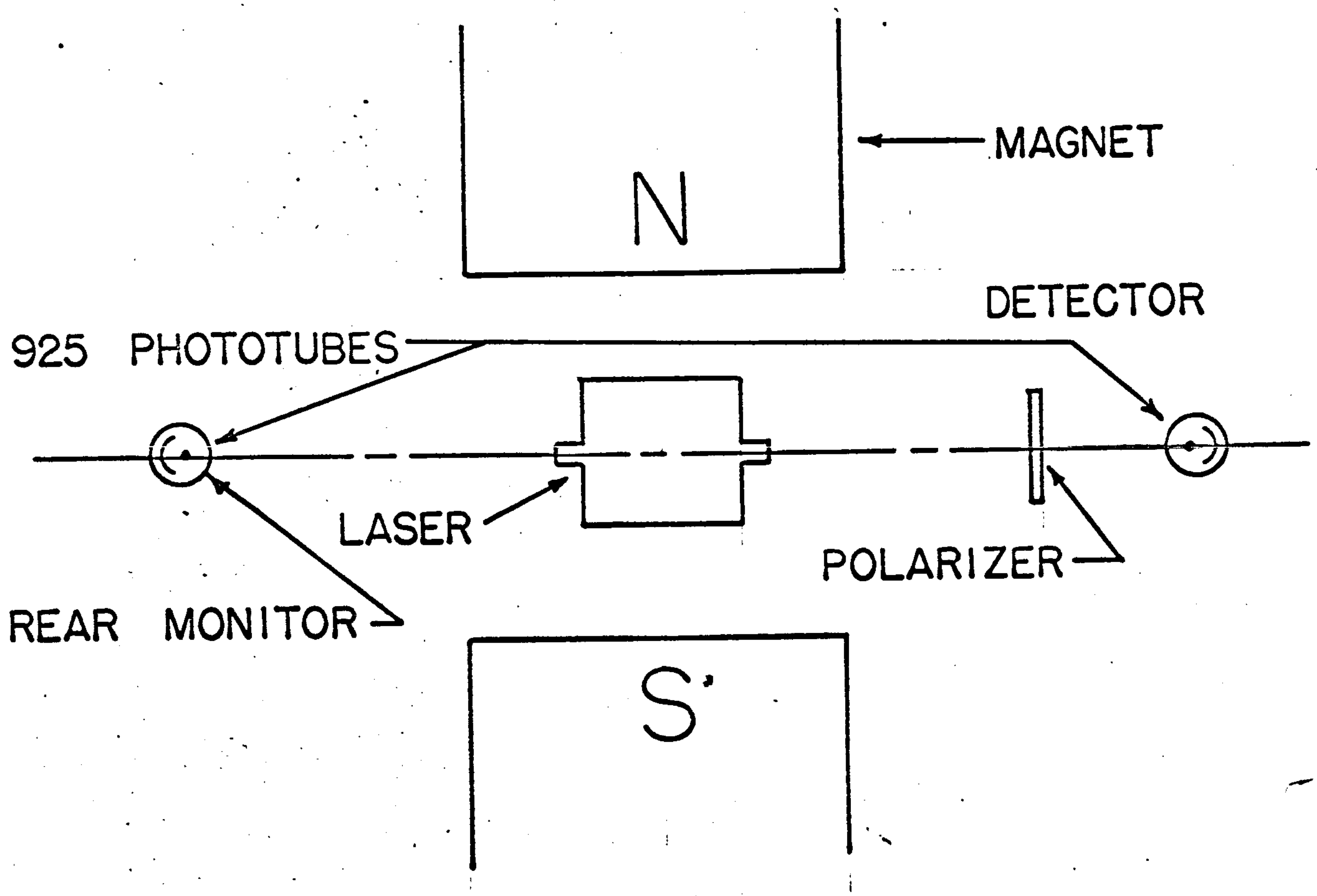

Figure 1
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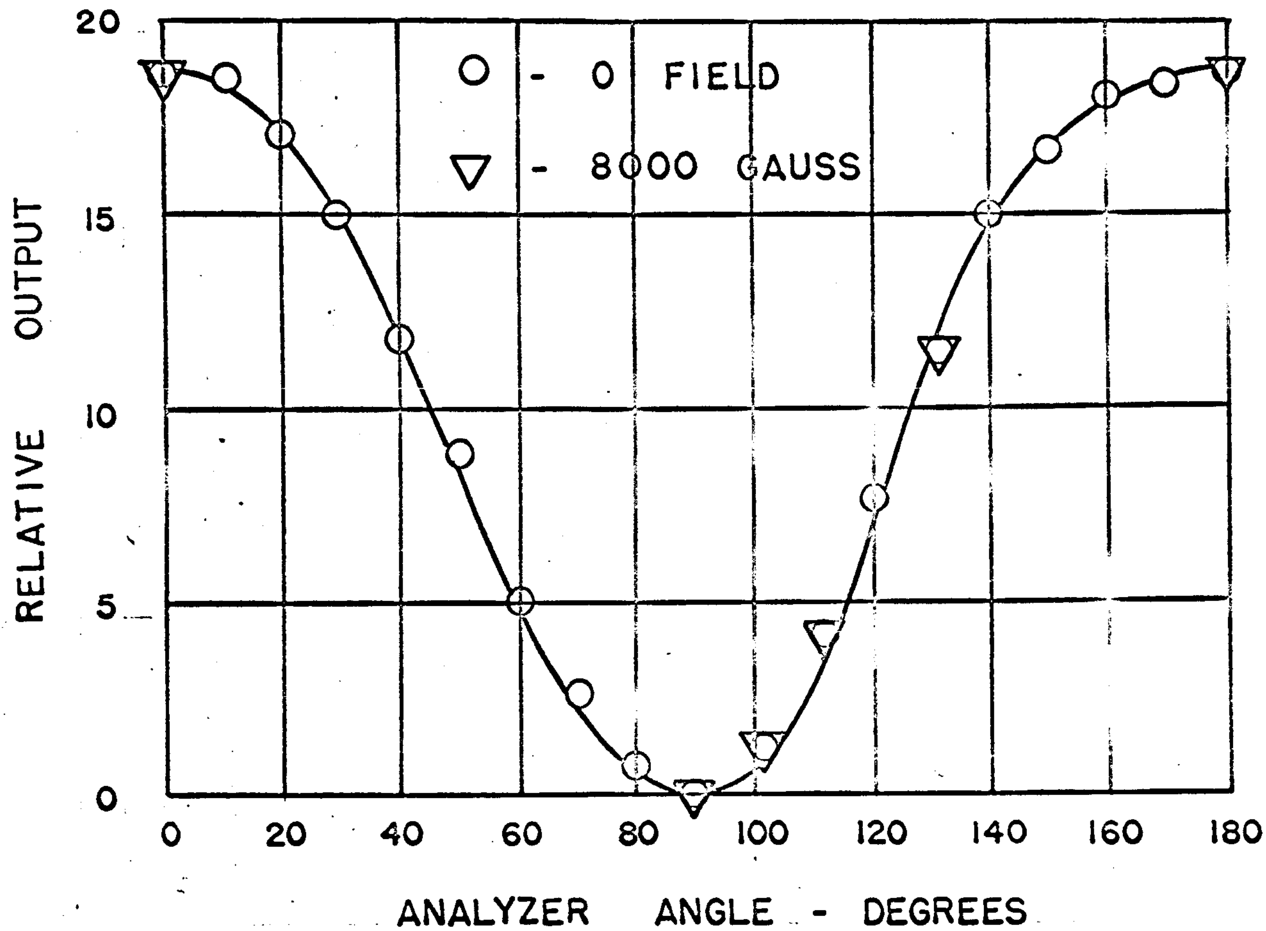

Figure 2

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